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| <b>TRANSMITTAL<br/>FORM</b><br><br>(to be used for all correspondence after initial filing) | Application Number   | 10/567,317             |              |
|   | Filing Date          | (Intl.) August 5, 2004 |              |
|   | First Named Inventor | Alan E. JONES          |              |
|   | Art Unit             | 2618                   |              |
|   | Examiner Name        | A. Rivero              |              |
| Total Number of Pages in This Submission  | 28                   | Attorney Docket Number | 562492006600 |

| ENCLOSURES (Check all that apply)  |  |   |
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| <div>Remarks</div>   |  |   |

| SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT |   |           |        |
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| Firm Name                                  | MORRISON & FOERSTER LLP (Customer No.: 20872) |           |        |
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| Printed name                               | Denise H. Wong                                |           |        |
| Date                                       | April 23, 2008                                | Reg. No.: | 59,622 |

|   |                              |
|---|------------------------------|
| I hereby certify that this paper is being deposited with the U.S. Postal Service as Express Mail, Airbill No. EV 958 961 559 US, on the date shown below in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. |                              |
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I hereby certify that this paper is being deposited with the U.S. Postal Service as Express Mail, Airbill No. EV 958 961 557 US, on the date shown below in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Dated: April 23, 2008

Signature

(Ariana Sanchez)

Docket No.: 562492006600  
(PATENT)

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Patent Application of:  
Alan E. JONES et al.

Application No.: 10/567,317

Confirmation No.: 6746

Filed: (Intl.) August 5, 2004

Art Unit: 2618

For: METHOD AND ARRANGEMENT FOR NOISE  
VARIANCE AND SIR ESTIMATION

Examiner: A. Rivero

**CLAIM FOR PRIORITY AND SUBMISSION OF DOCUMENTS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

Applicants hereby claim priority under 35 U.S.C. 119 based on the following prior foreign application filed in the following foreign country on the date indicated:

| <u>Country</u> | <u>Application No.</u> | <u>Date</u>    |
|----------------|------------------------|----------------|
| United Kingdom | 0318529.5              | August 7, 2003 |

In support of this claim, a certified copy of the said original foreign application is filed herewith.

Dated: April 23, 2008

Respectfully submitted,

By

Denise H. Wong

Registration No.: 59,622

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I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with patent application GB0318529.5 filed on 7 August 2003.

I also certify that the attached copy of the request for grant of a Patent (Form 1) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

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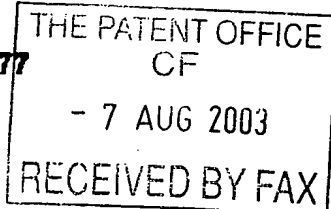
Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed



Dated 1 April 2008

Patents Form 1/77

Patents Act 1977  
(Rule 14)The  
Patent  
Office07AUG03 E83609-1 263975  
P01/7700 0340-0318529.5**Request for grant of a patent**

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form.)

The Patent Office

Cardiff Road  
Newport  
South Wales  
NP9 1RH

1. Your reference

03.042/2-ipw/ph

2. Patent application number

(The Patent Office will fill in this part)

0318529.5

- 7 AUG 2003

3. Full name, address and postcode of the or of each applicant (underline all surnames)

IPWireless, Inc.  
1001 Bayhill Drive, 2nd Floor  
San Bruno, California  
CA 94066

Patents ADP number (if you know it)

8169401002

If the applicant is a corporate body, give the country/state of its incorporation

USA, Delaware

4. Title of the invention

METHOD AND ARRANGEMENT FOR  
NOISE VARIANCE AND SIR ESTIMATION

5. Name of your agent (if you have one)

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7987423001

08414608001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country

Priority application number  
(if you know it)Date of filing  
(day / month / year)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing  
(day / month / year)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

Yes

a) any applicant named in part 3 is not an inventor, or  
b) there is an inventor who is not named as an applicant, or

c) any named applicant is a corporate body.

See note (d))

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0076669 07-Aug-03 08:35

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9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form

Description 15

Claim(s) 4

Abstract 1

Drawing(s) 3 only

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for preliminary examination and search (Patents Form 9/77)

Request for substantive examination (Patents Form 10/77)

Any other documents (please specify)

11. I/We request the grant of a patent on the basis of this application.

Signature

Date

Peter D. Hudson

7 August 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

Peter Hudson

01420 562568

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After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

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DUPLICATE

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- 1 -

METHOD AND ARRANGEMENT FOR NOISE VARIANCE AND SIR  
ESTIMATION

5 **Field of the Invention**

This invention relates to noise variance and signal/interference ratio (SIR) estimation, and particularly though not exclusively to such estimation in  
10 wireless communication receivers. It will be understood that, as used herein, the terms 'noise' and 'interference' are to be considered synonymous, with each encompassing both noise and interference.

15

**Background of the Invention**

In the field of this invention it is known that many parts of a wireless communications receiver often require  
20 an estimation of noise variance and/or SIR. This is needed for purposes of power control, threshold determination for various algorithms, quantisation of soft-decision information for channel decoding purposes to name but a few.

25

For BPSK (Binary Phase Shift Key) and QPSK (Quadrature Phase Shift Key) modulation the conventional method for estimating the SIR at the output of a detector relies on estimating output noise variance using the following  
30 equality known (for example) from the publication by

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Papoulis and Pillai, entitled 'Probability, Random Variables and Stochastic Processes', 3rd Ed. 1991,

$$\hat{\sigma}_i^2 = E\left(\left|\hat{d}_n^{(k)}\right|^2\right) - E\left(\left|\hat{d}_n^{(k)}\right|\right)^2$$

where  $\hat{\sigma}_i^2$  represents variance,  $E$  represents mean value  
 5 and  $\hat{d}_n^{(k)}$  represents the detector output.

This yields the following result:

$$SIR^{(k)} = \frac{P^{(k)} - \hat{\sigma}_i^2}{\hat{\sigma}_i^2} = \frac{E\left(\left|\hat{d}_n^{(k)}\right|\right)^2}{E\left(\left|\hat{d}_n^{(k)}\right|^2\right) - E\left(\left|\hat{d}_n^{(k)}\right|\right)^2}$$

where  $SIR$  represents the SIR of the  $k^{th}$  sequence at the  
 10 detector output, and  $P^{(k)}$  represents the average power of  
 the  $k^{th}$  sequence at the detector output.

However, this approach has the disadvantage(s) that the  
 accuracy of this method at low SIR is poor since it  
 15 suffers from a bias term. An analysis of the bias term  
 and a correction method has been suggested in GB patent  
 application no. 0128475.1. However, the suggested  
 correction method requires a look-up table to correct for  
 the aforementioned problem, and the estimation variance  
 20 is also increased when correcting the bias.

A need therefore exists for a method and arrangement for  
 noise variance and SIR estimation wherein the  
 abovementioned disadvantage(s) may be alleviated.

25

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**Statement of Invention**

In accordance with a first aspect of the present invention there is provided a method for noise variance  
5 estimation as claimed in claim 1.

In accordance with a second aspect of the present invention there is provided an arrangement for noise variance estimation as claimed in claim 10.

10

Preferably, the second noise variance signal is produced by applying to the first noise variance signal a function substantially equal to the detector's transfer function.

15 Preferably, the first noise variance signal is derived from a midamble portion of the received signal.

Preferably, an estimate of total power at the detector output is produced from the second noise variance signal  
20 and an SIR signal representative of SIR in the received signal.

**Brief Description of the Drawings**

25

One method and arrangement for noise variance and SIR estimation incorporating the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

30



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FIG. 1 shows a block schematic diagram illustrating a 3GPP radio communication system in which the present invention may be used;

5 FIG. 2 shows a block schematic diagram illustrating a generic burst structure employed in the system of FIG. 1; and

10 FIG. 3 shows a block schematic diagram illustrating a detector arrangement incorporating a noise variance and SIR estimator utilising the present invention.

15 **Description of Preferred Embodiment(s)**

The following preferred embodiment of the present invention will be described in the context of a 3GPP (3<sup>rd</sup> Generation Partnership Project) UMTS (Universal Mobile  
20 Telecommunication System) Radio Access Network (UTRAN) system operating in TDD mode. Referring firstly to FIG. 1, a typical, standard UTRAN system 100 is conveniently considered as comprising: a terminal/user  
25 equipment domain 110; a UMTS Terrestrial Radio Access Network domain 120; and a Core Network domain 130.

In the terminal/user equipment domain 110, terminal equipment (TE) 112 is connected to mobile equipment (ME) 114 via the wired or wireless R interface. The ME 114 is  
30 also connected to a user service identity module (USIM) 116; the ME 114 and the USIM 116 together are considered

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as a user equipment (UE) 118. The UE 118 communicates data with a Node B (base station) 122 in the radio access network domain 120 via the wireless *Uu* interface. Within the radio access network domain 120, the Node B 122

5 communicates with a radio network controller (RNC) 124 via the *Iub* interface. The RNC 124 communicates with other RNC's (not shown) via the *Iur* interface. The Node B 122 and the RNC 124 together form the UTRAN 126. The RNC 124 communicates with a serving GPRS service node (SGSN) 132

10 in the core network domain 130 via the *Iu* interface. Within the core network domain 130, the SGSN 132 communicates with a gateway GPRS support node (GGSN) 134 via the *Gn* interface; the SGSN 132 and the GGSN 134 communicate with a home location register (HLR) server

15 136 via the *Gr* interface and the *Gc* interface respectively. The GGSN 134 communicates with public data network 138 via the *Gi* interface.

Thus, the elements RNC 124, SGSN 132 and GGSN 134 are

20 conventionally provided as discrete and separate units (on their own respective software/hardware platforms) divided across the radio access network domain 120 and the core network domain 130, as shown the FIG. 2.

25 The RNC 124 is the UTRAN element responsible for the control and allocation of resources for numerous Node B's 122; typically 50 to 100 Node B's may be controlled by one RNC. The RNC also provides reliable delivery of user traffic over the air interfaces. RNC's communicate with

30 each other via the *Iur* interface.

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The SGSN 132 is the UMTS Core Network element responsible for Session Control and interface to the HLR. The SGSN keeps track of the location of an individual UE and performs security functions and access control. The SGSN  
5 is a large centralised controller for many RNCs.

The GGSN 134 is the UMTS Core Network element responsible for concentrating and tunnelling user data within the core packet network to the ultimate destination (e.g.,  
10 internet service provider - ISP).

Such a UTRAN system and its operation are described more fully in the 3GPP technical specification documents 3GPP TS 25.401, 3GPP TS 23.060, and related documents,  
15 available from the 3GPP website at [www.3gpp.org](http://www.3gpp.org), and need not be described in more detail herein.

The physical layer of UTRA TDD mode provides physical channels that carry transport channels from the MAC  
20 (Medium Access Control) sub-layer of UMTS Layer 2. A physical channel is defined by frequency, timeslot, channelisation code, burst type, and radio frame allocation. In UMTS Layer 2, in each time slot, three burst structures (as shown generically in FIG. 2) can be  
25 supported, each consisting of two data fields (210, 230), a midamble (220) and a guard period (240).

The data fields contain the data symbols from the transport channels, after the processes of coding,  
30 multiplexing, interleaving, and modulation. The midamble field contains the training sequence, which is used in a

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number of Layer 1 algorithms, such as channel estimation. The guard period, GP, is used to accommodate any timing inaccuracies, from propagation delays, channel dispersion, and power ramping in the transmitter. The

5 different burst types and their associated field lengths in chips are given in the table below:

| Burst Type   | Data Field 1 | Data Field 2 | Midamble $L_m$ | GP  |
|--------------|--------------|--------------|----------------|-----|
| Burst Type 1 | 976          | 976          | 512            | 96  |
| Burst Type 2 | 1104         | 1104         | 256            | 96  |
| Burst Type 3 | 976          | 880          | 512            | 192 |

The received sequence in the data payload areas of the

10 burst is given by

$$\mathbf{e} = \mathbf{A}\mathbf{d} + \mathbf{n}$$

where

$$\mathbf{d} = (\mathbf{d}^{(1)T}, \mathbf{d}^{(2)T}, \dots, \mathbf{d}^{(K)T})^T = (d_1, d_2, \dots, d_{KN})^T,$$

$(\cdot)^T$  denotes transposition,  $K$  is the number of data

15 sequences  $k=1, \dots, K$ , and  $N$  is the number of symbols per data sequence  $n=1, \dots, N$ . The data sequence for the  $k^{\text{th}}$  user is given by  $\mathbf{d}^{(k)} = (d_1^{(k)}, d_2^{(k)}, \dots, d_N^{(k)})^T$ . The noise sequence  $\mathbf{n}$ , denoted by  $\mathbf{n} = (n_1, n_2, \dots, n_{NQ+W-1})^T$ , has zero mean and covariance matrix  $\mathbf{R}_n = E(\mathbf{n}\mathbf{n}^H)$ , where  $(\cdot)^H$  denotes conjugate

20 transposition. The matrix has dimensions  $(NQ+W-1) \times KN$  and the elements are given by:

$$A_{Q(s-1)+l, N(k-1)+n} = \begin{cases} \mathbf{b}^{(k)} & k=1 \dots K, l=1 \dots Q+W-1, n=1 \dots N \\ 0 & \text{else} \end{cases}$$

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where  $\mathbf{b}^{(k)} = \mathbf{h}^{(k)} * \mathbf{c}^{(k)}$ ,  $\mathbf{h}^{(k)}$  is the impulse response of the  $k^{\text{th}}$  user,  $W$  is the length of the channel impulse response,  $*$  denotes discrete time convolution,  $\mathbf{c}^{(k)}$  is the spreading code of the  $k^{\text{th}}$  user and  $Q$  is the length of the spreading  
 5 sequence in chips.

The output of the detector is given by

$$\hat{\mathbf{d}} = f(\mathbf{e}) = \mathbf{r} + \mathbf{z}$$

where  $f(\cdot)$  denotes the transfer function of the detector,  
 10 the vector  $\mathbf{r}$  contains the desired symbols, and the vector  $\mathbf{z}$  contains noise plus interference. The average power for the  $k^{\text{th}}$  sequence at the output of the detector is given by

$$P^{(k)} = E\left(\left|\hat{d}_n^{(k)}\right|^2\right)$$

15 Expanding  $P^{(k)}$  produces

$$P^{(k)} = E\left(\left|r_{n+(k-1)Q}\right|^2\right) + E\left(r_{n+(k-1)Q} z_{n+(k-1)Q}^*\right) + E\left(r_{n+(k-1)Q}^* z_{n+(k-1)Q}\right) + E\left(\left|z_{n+(k-1)Q}\right|^2\right)$$

Under the assumption that the noise is uncorrelated with the signal vector  $\mathbf{r}$ , the average power for the  $k^{\text{th}}$   
 20 sequence becomes

$$P^{(k)} = E\left(\left|r_{n+(k-1)Q}\right|^2\right) + \sigma_z^2$$

where  $E(\cdot)$  is the statistical average,  $\sigma_z^2 = E\left(\left|z_{n+(k-1)Q}\right|^2\right)$  is the noise variance at the output of the detector, and  $E\left(\left|r_{n+(k-1)Q}\right|^2\right)$  is the signal power for the  $k^{\text{th}}$  sequence. The  
 25 SIR at the output of the detector for the  $k^{\text{th}}$  sequence is therefore given by

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$$SIR^{(k)} = \frac{P^{(k)} - \sigma_i^2}{\sigma_i^2} = \frac{E\left(\left|r_{n+(k-1)Q}\right|^2\right)}{\sigma_i^2}$$

The conventional method for estimating the SIR relies on estimating the detector output noise variance using the following equality mentioned above:

$$\hat{\sigma}_i^2 = E\left(\left|\hat{d}_n^{(k)}\right|^2\right) - E\left(\left|\hat{d}_n^{(k)}\right|\right)^2$$

to yield the following result:

$$SIR^{(k)} = \frac{P^{(k)} - \hat{\sigma}_i^2}{\hat{\sigma}_i^2} = \frac{E\left(\left|\hat{d}_n^{(k)}\right|\right)^2}{E\left(\left|\hat{d}_n^{(k)}\right|^2\right) - E\left(\left|\hat{d}_n^{(k)}\right|\right)^2}$$

As discussed above, the accuracy of this approach at low SIR is poor since it suffers from a bias term, which may be corrected by use of a look-up table.

As will be discussed in greater detail below, the following preferred embodiments of the present invention do not suffer from such a bias term and therefore do not require a look-up table to correct for the aforementioned problem.

Referring now to FIG. 3, in detector arrangement 300 (which may be used in Node B 122 or User Equipment 118) a new technique for estimating the SIR at the output of a detector 310 uses an estimate of the detector input noise variance (derived in channel estimator 320) to provide an estimate of the detector output noise variance (derived in SIR estimator 330). In the channel estimator 320 the detector input noise variance is derived from the

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midamble portion of the burst using locally reconstructed replicas of the transmitted signal which are removed from the received set of samples providing a residual term that contains the noise of the channel. In the SIR  
5 estimator 330, by deriving the transfer function of the detector an estimate of the detector output noise variance is estimated.

The estimated output noise variance then allows an  
10 improved estimate of the SIR ( $SIR^{(i)} \dots SIR^{(k)}$ ) at the detected output. Typically, the SIR at the output of the detector is used for deriving soft decision quantisation levels for application to channel decoding algorithms.

15 In the following description, two types of CDMA (Code Division Multiple Access) detector are considered, namely single user detector (SUD) and multiuser detector (MUD). It will be understood that the invention is also applicable to other types of detector such as a RAKE  
20 receiver.

The technique described here is based on first estimating the noise variance at the input to the detector and then mapping the input noise variance to the output noise  
25 variance using the transfer function of the detector.

The process of estimating the noise variance at the input to the detector is carried out using the midamble portion of the burst. Considering the received sequence of chip  
30 spaced samples  $\mathbf{e} = (e_1, e_2, \dots, e_{L_s})^T$ , where  $L_s$  is the burst

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length, a locally reconstructed version for the midamble portion of the burst is defined as follows:

$$\bar{\mathbf{e}} = (\bar{e}_1, \bar{e}_2, \dots, \bar{e}_{L_m+W-1})^T = \left( \sum_k (\mathbf{h}^{(k)} * \mathbf{m}^{(k)}) \right)^T$$

where  $\bar{\mathbf{e}}$  denotes locally reconstructed version and  $\mathbf{m}^{(k)}$  is the midamble sequence of the  $k^{\text{th}}$  user. The noise variance estimate at the input to the detector is given by

$$\hat{\sigma}^2 = E \left( (e_W, e_{W+1}, \dots, e_X) - (\bar{e}_W, \bar{e}_{W+1}, \dots, \bar{e}_X)^2 \right)$$

where  $X \leq L_m$  and the starting position is  $W$  since the first  $W-1$  samples from the midamble portion of the burst are corrupted by the data portion of the burst.

#### Multiuser Detection

Under the assumption that the noise is white with variance  $\sigma^2$ , the Minimum Mean Squared Error (MMSE) block linear equalizer solution to symbol estimation is given (as known from the publication of Klein, Kaleh and Baier entitled 'Zero Forcing and Minimum Mean-Square-Error Equalization for Multiuser Detection in Code-Division Multiple-Access Channels' in IEEE Trans VT, VOL.45, No.2, May 1996, pp276-287) by

$$\hat{\mathbf{d}} = (\mathbf{A}^H \mathbf{A} + \sigma^2 \mathbf{I})^{-1} \mathbf{A}^H \mathbf{e} = \mathbf{f}(\mathbf{e}) = \mathbf{r} + \mathbf{z}$$

where  $\mathbf{I}$  is the identity matrix and

$$\mathbf{r} = (\mathbf{A}^H \mathbf{A} + \sigma^2 \mathbf{I})^{-1} \mathbf{A}^H \mathbf{A} \mathbf{d} = (r_1, r_2, \dots, r_{KN})^T \quad (1)$$

$$\mathbf{z} = (\mathbf{A}^H \mathbf{A} + \sigma^2 \mathbf{I})^{-1} \mathbf{A}^H \mathbf{n} = (z_1, z_2, \dots, z_{KN})^T \quad (2)$$



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From equation (2), the noise variance seen at the output of the MUD is given by

$$\sigma_r^2 = E\left(|z_{n+(k-1)Q}|^2\right) = \left(\|\mathbf{b}^{(k)}\|^2 + \sigma^2\right)^{-2} \|\mathbf{b}^{(k)}\|^2 \sigma^2$$

where  $\|\cdot\|$  denotes vector norm, and  $\sigma^2$  represents the noise variance at the input of the MUD. By replacing  $\sigma^2$  with the estimate of the MUD input noise variance  $\hat{\sigma}^2$ , we have a direct method for estimating the MUD output noise variance  $\hat{\sigma}_r^2$ . For completeness, the estimate  $\hat{\sigma}_r^2$  of the MUD output noise variance can be written as

$$\hat{\sigma}_r^2 = f(\hat{\sigma}^2) = \left(\|\mathbf{b}^{(k)}\|^2 + \hat{\sigma}^2\right)^{-2} \|\mathbf{b}^{(k)}\|^2 \hat{\sigma}^2$$

where  $f(\hat{\sigma}^2)$  represents the noise transfer function of the detector.

Using the new estimate for the output noise variance, the SIR at the output of the MUD for the  $k^{\text{th}}$  sequence is defined by

$$SIR^{(k)} = \frac{E\left(|r_{n+(k-1)Q}|^2\right) + \delta(\hat{\sigma}^2)}{\hat{\sigma}_r^2}$$

where the error term  $\delta(\hat{\sigma}^2)$  is given by

$$\delta(\hat{\sigma}^2) = \|\mathbf{b}^{(k)}\|^2 \left( \frac{\sigma^2}{\left(\|\mathbf{b}^{(k)}\|^2 + \sigma^2\right)^2} - \frac{\hat{\sigma}^2}{\left(\|\mathbf{b}^{(k)}\|^2 + \hat{\sigma}^2\right)^2} \right)$$

It is clear from the above set of equations that when  $\hat{\sigma}^2 = \sigma^2$  we have the following

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$$SIR^{(k)} = \frac{E\left\{r_{n+(k-1)Q}^2\right\}}{\sigma^2}$$

It will therefore be understood that the accuracy of the above technique is directly related to the quality of the noise variance estimate,  $\hat{\sigma}^2$ , at the input of the MUD.

#### Single User Detection

For the single user detector case the received sequence is written as

$$\mathbf{e} = \mathbf{A}\mathbf{d} + \mathbf{n} = \mathbf{H}\mathbf{C}\mathbf{d} + \mathbf{n}$$

The matrix  $\mathbf{H}$  has dimensions  $(NQ+W-1) \times NQ$  and its elements are given by

$$H_{i,v} = \begin{cases} h_{i-v+1} & 1 \leq i-v+1 \leq W \\ 0 & \text{else} \end{cases}$$

where  $\mathbf{h} = (h_1, h_2, \dots, h_W)^T$ ,  $i = 1, \dots, NQ+W-1$ , and  $v = 1, \dots, NQ$ . The matrix  $\mathbf{C}$  has dimensions  $NQ \times KN$  and its elements are given by

$$C_{Q(n-1)+q, N(k-1)+n} = \begin{cases} c_q^{(k)} & q = 1, \dots, Q, n = 1, \dots, N, k = 1, \dots, K \\ 0 & \text{else} \end{cases}$$

For Minimum Mean Squared Error (MMSE) symbol estimation and under the assumption that the noise is white with variance  $\sigma^2$ , the output of the SUD is given by

$$\hat{\mathbf{d}} = \mathbf{C}^H (\mathbf{H}^H \mathbf{H} + \sigma^2 \mathbf{I})^{-1} \mathbf{H}^H \mathbf{e} = \mathbf{f}(\mathbf{e}) = \mathbf{r} + \mathbf{z}$$

where

$$\mathbf{r} = \mathbf{C}^H (\mathbf{H}^H \mathbf{H} + \sigma^2 \mathbf{I})^{-1} \mathbf{H}^H \mathbf{H} \mathbf{C} \mathbf{d} = (r_1, r_2, \dots, r_{KN})^T \quad (3)$$

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$$\mathbf{z} = \mathbf{C}^H (\mathbf{H}^H \mathbf{H} + \sigma^2 \mathbf{I})^{-1} \mathbf{H}^H \mathbf{n} = (z_1, z_2, \dots, z_{KN})^T \quad (4)$$

From equation (4), the noise variance seen at the output of the SUD is given by

$$5 \quad \sigma_r^2 = E(|z_{n+(k-1)Q}|^2) = G \times (\|\mathbf{h}\|^2 + \sigma^2)^2 \|\mathbf{h}\|^2 \sigma^2$$

where  $\|\cdot\|$  denotes vector norm, the multiplier  $G$  comes from the matrix  $\mathbf{C}$ , and in general  $G = \|\mathbf{c}^{(k)}\|^2 = Q$ .

By replacing  $\sigma^2$  with the estimate of the SUD input noise variance  $\hat{\sigma}^2$ , we have a direct method for estimating the SUD output noise variance  $\sigma_r^2$ . For completeness, the estimate  $\hat{\sigma}_r^2$  of the SUD output noise variance can be written as

$$\hat{\sigma}_r^2 = f(\hat{\sigma}^2) = Q \times (\|\mathbf{h}\|^2 + \hat{\sigma}^2)^2 \|\mathbf{h}\|^2 \hat{\sigma}^2$$

15 where  $G$  is replaced with  $Q$  and  $f(\hat{\sigma}^2)$  is the noise transfer function of the detector. Using the new estimate for the output noise variance, the SIR at the output of the SUD for the  $k^{\text{th}}$  sequence is defined by

$$SIR^{(k)} = \frac{E(|r_{n+(k-1)Q}|^2) + \delta(\hat{\sigma}^2)}{\hat{\sigma}_r^2}$$

20 where the error term  $\delta(\hat{\sigma}^2)$  is given by

$$\delta(\hat{\sigma}^2) = Q \times \|\mathbf{h}\|^2 \left( \frac{\sigma^2}{(\|\mathbf{h}\|^2 + \sigma^2)^2} - \frac{\hat{\sigma}^2}{(\|\mathbf{h}\|^2 + \hat{\sigma}^2)^2} \right)$$

It is clear from the above set of equations that when  $\hat{\sigma}^2 = \sigma^2$  we have the following

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$$SIR^{(k)} = \frac{E\left(\left|r_{n+(k-1)Q}\right|^2\right)}{\sigma_r^2}$$

It will therefore be understood that the accuracy of the above technique is directly related to the quality of the noise variance estimate,  $\hat{\sigma}^2$ , at the input of the SUD.

It will be appreciated that the method described above for noise variance and SNIR estimation may be carried out in software running on a processor (not shown - e.g., in User Equipment such as 118 or a Node B such as 122), and that the software may be provided as a computer program element carried on any suitable data carrier (also not shown) such as a magnetic or optical computer disc.

It will be also be appreciated that the arrangement described above for noise variance and SNIR estimation may alternatively be carried out in hardware, for example in the form of an integrated circuit (not shown) such as an FPGA (Field Programmable Gate Array) or ASIC (Application Specific Integrated Integrated Circuit).

It will be understood that the method and arrangement for noise variance and SIR estimation described above provides the following advantages that the accuracy of this technique is not poor at low SIR, since it does not suffer from a bias term, nor does it require correction therefor using a look-up table. An additional advantage is that any increase in estimation variance resulting from bias correction may be avoided.

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**Claim(s)**

1. A method for noise variance estimation of a detected signal, the method comprising:
  - 5 receiving a signal and producing therefrom in a detector a detected signal;  
producing from the received signal a first noise variance signal representative of noise variance in the received signal; and
  - 10 producing from the detected signal and the first noise variance signal a second noise variance signal representative of noise variance estimation in the received signal.
- 15 2. The method of claim 1 wherein the step of producing the second noise variance signal comprises applying to the first noise variance signal a function substantially equal to the detector's transfer function.
- 20 3. The method of claim 1, 2 or 3 wherein the step of producing the first noise variance signal comprises deriving the first noise variance signal from a midamble portion of the received signal.
- 25 4. The method of claim 1, 2 or 3 further comprising:  
producing from the second noise variance signal and an estimate of total power at the detector output an SIR signal representative of SIR in the received signal.

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5. The method of any one of claims 1-4 wherein the detector is a CDMA multi-user detector.
6. The method of any one of claims 1-4 wherein the  
5 detector is a CDMA single-user detector.
7. The method of any one of claims 1-4 wherein the detector comprises a CDMA RAKE receiver.
- 10 8. The method of any one of claims 1-7 wherein the received signal is a wireless signal.
9. The method of claim 8 wherein the wireless signal is a UMTS air interface signal.
- 15
10. An arrangement for noise variance estimation of a detected signal, the arrangement comprising:  
a detector for receiving a signal and detecting therein a detected signal;  
20 first noise variance means for producing from the received signal a first noise variance signal representative of noise variance in the received signal;  
second noise variance means for producing from the  
25 detected signal and the first noise variance signal a second noise variance signal representative of noise variance estimation in the received signal.
- 30 11. The arrangement of claim 10 wherein the second noise variance means is arranged to apply to the first noise

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variance signal a function substantially equal to the detector's transfer function to produce the second noise variance signal.

5 12. The arrangement of claim 10 or 11 wherein the first noise variance means is arranged to derive the first noise variance signal from a midamble portion of the received signal.

10 13. The arrangement of claim 10, 11 or 12 further comprising:

SIR estimation means for producing from second noise variance signal and an estimate of total power at the detector output an SIR signal representative  
15 of SIR in the received signal.

14. The arrangement of any one of claims 10-13 wherein the detector is a CDMA multi-user detector.

20 15. The arrangement of any one of claims 10-13 wherein the detector is a CDMA single-user detector.

16. The arrangement of any one of claims 10-13 wherein the detector comprises a CDMA RAKE receiver.

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17. The arrangement of any one of claims 10-16 wherein the received signal is a wireless signal.

18. The arrangement of claim 17 wherein the wireless  
30 signal is a UMTS air interface signal.

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19. A communication receiver comprising the arrangement of any one of claims 10 to 17.

20. User equipment for use in a wireless communication system, the user equipment comprising the communication receiver of claim 19.

21. A base station for use in a wireless communication system, the base station comprising the communication receiver of claim 19.

22. A computer program element comprising computer program means for performing the method of any one of claims 1 to 9.

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23. An integrated circuit comprising the arrangement of any one of claims 10 to 18.

24. A method for noise variance estimation substantially as hereinbefore described with reference to the accompanying drawings.

25. An arrangement for noise variance estimation substantially as hereinbefore described with reference to the accompanying drawings.



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**Abstract****METHOD AND ARRANGEMENT FOR NOISE VARIANCE AND SIR  
ESTIMATION**

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A method and arrangement (300) for noise variance and SIR estimation in a UTRAN Node B (122) or User Equipment (118) estimates the SIR ( $SIR^{(i)}-SIR^{(k)}$ ) at the output of a detector (310) by using an estimate ( $\hat{\sigma}^2$ ) of the detector input noise variance to provide an estimate ( $\hat{\sigma}_d^2$ ) of the detector output noise variance. The detector input noise variance is derived from a midamble portion (220) in the received signal. By deriving the transfer function of the detector an estimate of the detector output noise variance is estimated. The estimated output noise variance then allows an improved estimate of the SIR ( $SIR^{(i)}-SIR^{(k)}$ ) at the detected output.

The accuracy of this technique is not poor at low SIR, since it does not suffer from a bias term, nor does it require correction therefor using a look-up table. Also, any increase in estimation variance resulting from bias correction may be avoided.

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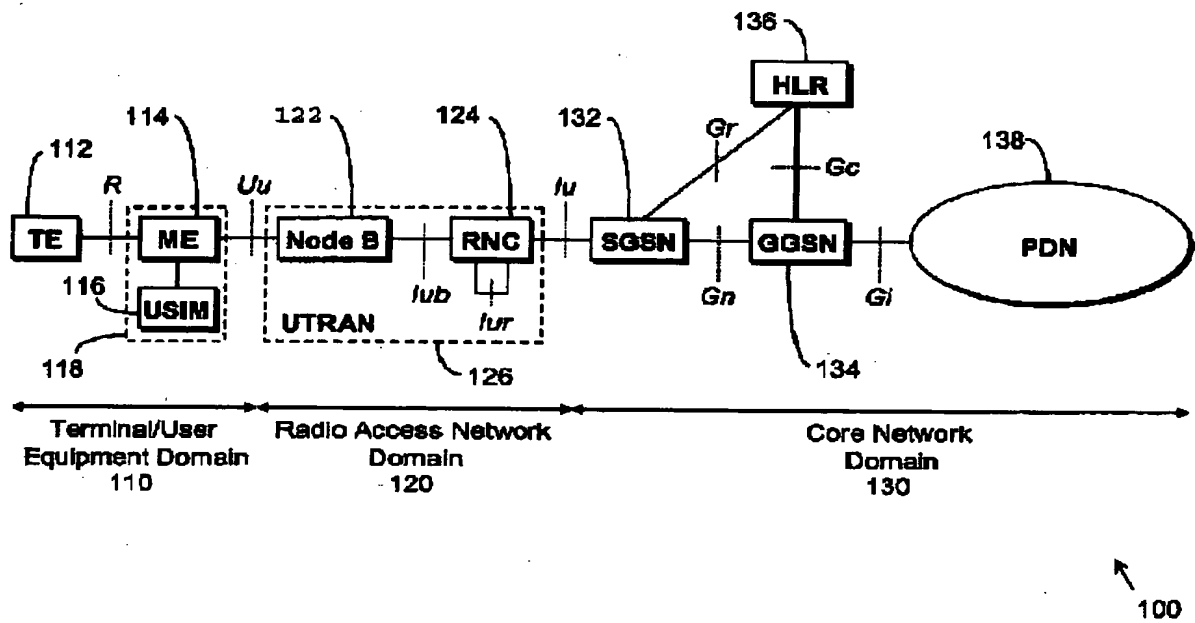


FIG. 1

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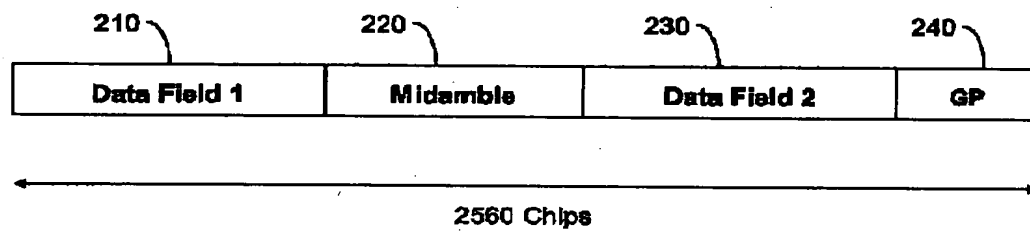


FIG. 2

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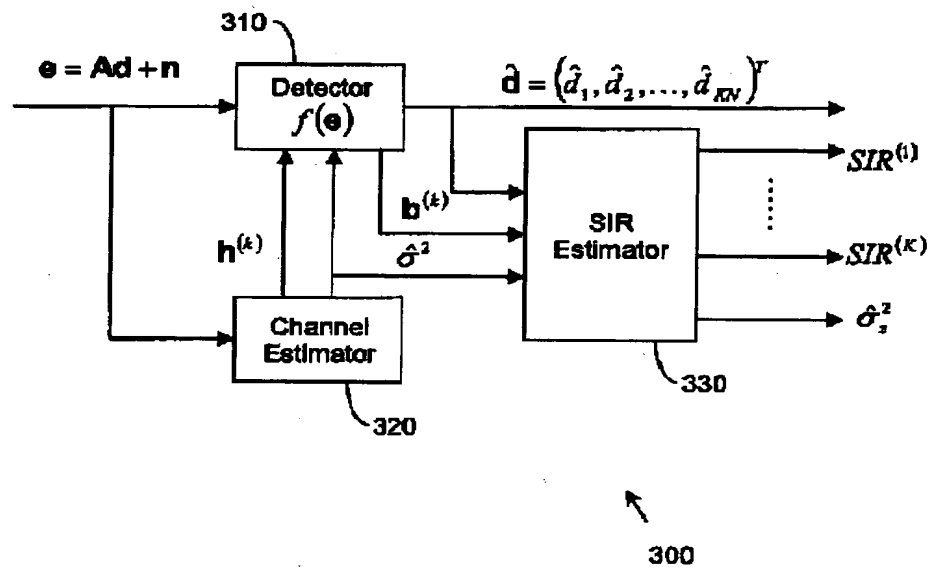


FIG. 3